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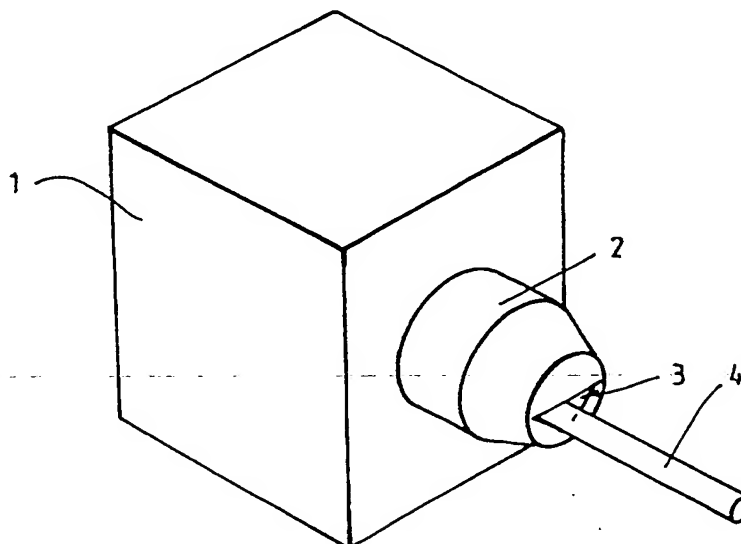
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶: G05B 19/19, 19/404, B23Q 15/013, B23B 5/18	A1	(11) International Publication Number: WO 99/10785 (43) International Publication Date: 4 March 1999 (04.03.99)
(21) International Application Number: PCT/AU98/00644 (22) International Filing Date: 14 August 1998 (14.08.98) (30) Priority Data: PO 8768 25 August 1997 (25.08.97) AU (71) Applicant (for all designated States except US): ANCA PTY. LTD. [AU/AU]; 25 Gatwick Road, Bayswater North, VIC 3153 (AU). (72) Inventors; and (75) Inventors/Applicants (for US only): BOLAND, Patrick [AU/AU]; 75 Alfred Street, Kew, VIC 3101 (AU). KAGANOV, Anatoly [AU/AU]; 2A Shoobra Road, Elsternwick, VIC 3185 (AU). (74) Agent: CARTER SMITH & BEADLE; 2 Railway Parade, P.O. Box 557, Camberwell, VIC 3124 (AU).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: AN IMPROVED CLAMPING DEVICE AND METHOD OF OPERATION FOR A CNC MACHINE

**(57) Abstract**

A computer numerically controlled (CNC) machine has a chuck (2) rotatable about a first axis (A) and a V-block clamp (3) for clamping a workpiece (4) with its central longitudinal axis (C) extending parallel to the first axis (A). The offset (d) between the axes (A) and (C) is known or calculated and the CNC machine is programmed to compensate for the offset (d) during operation of a cutting tool (5) upon the workpiece (4). The V-block clamp (3) can accommodate workpieces of different diameters without having to align the central longitudinal axis (C) of each workpiece to coincide with the axis of rotation of the chuck (2), resulting in a reduction in set up time and an increased concentricity of a ground workpiece compared with conventional CNC grinding machines.

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AN IMPROVED CLAMPING DEVICE AND METHOD
OF OPERATION FOR A CNC MACHINE

This invention relates to multi-axis computer numerically controlled (CNC) machines having a cutting tool that is designed to operate upon a
5 workpiece. In the context of this invention, the term cutting tool is not restricted to standard turning or milling cutters, but also includes all mechanical, electronic and/or electro-mechanical devices used to modify the shape of a workpiece. Examples of cutting tools include: end-mills, turning tools, grinding wheels, laser cutting beams, plasma beams and punch tools. This
10 invention is particularly applicable to a CNC machine in which a cutting tool, such as a grinding wheel, is moved to operate on a workpiece mounted in a rotatable chuck or headstock.

The development of multi axes and multifunction machine tools in conjunction with the development of sophisticated computer controlled
15 operations has facilitated the emergence of a generation of very high speed precision machine tools capable of complex multi-step operations from one machine.

Such machine tools typically hold a workpiece in a controlled position whilst a movable cutting tool acts upon the workpiece to perform the desired
20 task. The workpiece is traditionally held such that its central longitudinal axis coincides with the rotational axis of the headstock.

Typically a CNC machine is controlled by a computer program, called a part program, which serially instructs the machine to perform a sequential series of discrete operations in a predetermined sequence so that the movable
25 operative part moves along a programmed path determined by the part program. Each individual instruction is termed a "block" and many constitute a determining command for each or a combination of controllable axes. For example, a block may instruct a grinding wheel to move 5mm in the Y axis at a given velocity. Multiple axis blocks may instruct a grinding wheel to rotate

and move forward 0.05mm in the X and Y axis at a given velocity. The blocks, once programmed into the computer, are then fixed in a set sequential order. The whole set of sequential blocks may then be automatically operated by the CNC machine which then operates from start to finish of the part program.

5 CNC machines conventionally include a trajectory interpolator and a position controller. The trajectory interpolator produces interpolated position commands from inputs representing a feedrate specification, i.e. All the data required to determine the desired feedrate along the programmed path, and high level motion commands, the machine's internal numeric representation of the data required to interpolate the machine along the desired path to the end point
10 of the current block.

The interpolation mode comprises a specification of the geometric path to be traversed by the grinding wheel from the programmed start point to the programmed end point.

15 An interpolated position command is a "snap-shot" of the desired machine position at some position on the programmed path. One interpolated position command is generated by the trajectory interpolator once every machine update period.

The position controller of the CNC machine conventionally receives the
20 interpolated position commands every machine update period and performs a control algorithm that causes the cutting tool to attempt to attain the position determined from the interpolated position command.

Conventional CNC tool grinding machines have the workpiece held by a collet with the centre of the workpiece in line with the rotational axis of the
25 headstock. This method is subject to inaccuracy when aligning the centre of the workpiece with the rotational axis of the headstock. Accurate alignment is essential for concentricity of the ground workpiece.

The inability to set up for workpieces of varying diameters without changing or adjusting the machine's collet reduces the flexibility and
30 productivity of the conventional CNC tool grinding machine. The time spend

on setup is unproductive and therefore undesirable.

A further limitation of the traditional collect method is limited rigidity of the length of the workpiece when subjected to the grinding means.

In order to reduce setup time and increase setup accuracy several types
5 of workpiece clamps have been proposed.

One such mounting means which has been proposed for holding and rotating a workpiece is known alternatively as a "sidelock holder" or an "end mill holder". Such a holder assembly is fitted to the collet. The workpiece is fitted within the end of the holder. The holder assembly requires a different
10 sized mechanism to be fitted for each different sized workpiece. This method also requires manual adjustment. The holder provides greater rigidity than conventional mounting means but the need to fit a different assembly for varying workpiece sizes and manual adjustment requirement increase set up time. As such, the holder is not very practical in a CNC machine. Further, the
15 holder does not address the problem of accurately setting up the centre of the workpiece to coincide with the centre of the headstock.

It is therefore desirable to provide a multi-axis CNC machine including workpiece mounting assembly which is adapted to hold workpieces of a range of diameters, which provides rigid support for the workpiece and which enables
20 concentric grinding with minimal set up time.

It is also desirable to provide a multi-axis CNC machine, and a method of operating a CNC machine, which does not require accurate alignment of the centre of the workpiece with the centre of the headstock and therefore reduces setup time.

25 According to one aspect of the invention there is provided a method of controlling a CNC machine having workpiece mounting means for holding a workpiece and a cutting tool operable upon the workpiece under the control of the CNC machine, the workpiece mounting means being rotatable about a first axis, the method being characterised by the steps of:

30 clamping the workpiece such that a longitudinal axis of the workpiece is

parallel to the first axis and offset from the first axis by a known or calculated distance; and

programming the CNC machine to compensate for said offset during operation of the cutting tool on the workpiece.

- 5 According to another aspect of the invention there is provided a computer numerically controlled (CNC) machine having workpiece mounting means for holding and rotating a workpiece, and a cutting tool operable upon the workpiece under the control of the CNC machine wherein the workpiece mounting means is rotatable about a first axis and includes workpiece clamping
10 means for clamping workpieces of different transverse dimensions in such a manner that a workpiece is clamped with a longitudinal axis of the clamped workpiece parallel to the first axis, the offset between the first axis and the longitudinal axis of the workpiece being known or calculated, and wherein the CNC machine is programmed to compensate for said offset during operation of
15 the cutting tool upon the workpiece.

The present invention is particularly applicable to CNC grinding machines for operating on workpieces having at least a cylindrical mounting portion. When such a workpiece is clamped with the central longitudinal axis of the cylindrical mounting portion extending parallel to, but offset from, the
20 first axis, the workpiece revolves in an orbit around the first axis and, with the amount of offset being known or calculated, it is a relatively simple matter to program the CNC machine to compensate for the offset when controlling movement of the cutting tool.

- Preferably, the workpiece clamping means comprises a first clamping jaw
25 that is fixed relative to the first axis about which the mounting means is rotatable and a second clamping jaw that is movable towards and away from the first clamping jaw. This is in contrast to rotatable chucks or collets of conventional CNC grinding machines which have a plurality of workpiece clamping jaws, each of which is movable relative to the axis of rotation of the
30 chuck or collet.

One of the advantages of the present invention over conventional CNC grinding machines is that the workpiece clamping means can accommodate workpieces of different diameters without having to align the central longitudinal axis of each different diameter workpiece to coincide with the axis of rotation of the headstock, chuck or collet. Instead, the offset for each different diameter workpiece is already known, or can be readily calculated, and so the control program for the cutting tool of the CNC machine can automatically compensate for the offset of a particular diameter workpiece. This can result in a marked reduction in set up time when changing workpieces as opposed to conventional CNC grinding machines. Another advantage of the present invention is an increased concentricity of a ground workpiece, as inaccuracies in conventional CNC grinding machines caused by aligning the central axis of the workpiece with the rotational axis of the headstock are eliminated.

In a particularly preferred embodiment, the fixed clamping jaw of the clamping means is in the form of a V-block, having planar workpiece supporting surfaces extending at an angle relative to one another. Such a V-block provides rigid support for a clamped workpiece. Further, a V-block can be accurately formed with the planar workpiece supporting surfaces extending parallel to the axis of rotation of the mounting means. The movable clamping jaw of the clamping means may be moved towards and away from the fixed clamping jaw by any convenient operating mechanism. In one preferred arrangement, the movable clamping jaw is mounted on a pivotal lever arm. The lever arm may be conveniently pivoted by a pneumatic operating mechanism including a plunger which is engageable with a rear end of the lever arm.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic perspective view of a workpiece clamping device for clamping workpieces of different diameters in a CNC machine;

Figure 2 is a schematic side view of the workpiece clamping device of Figure 1;

Figure 3 is a schematic front view showing a small diameter workpiece clamped in the workpiece clamping device;

5 Figure 4 is a schematic front view of a larger diameter workpiece clamped in the workpiece clamping device;

Figure 5 is a block diagram of the control system for the cutting tool of the CNC machine;

10 Figure 6 is a section through a CNC machine headstock including a preferred form of a workpiece clamping device;

Figure 7 is a front view of the headstock and workpiece clamping device of Figure 6;

Figure 8 is a section through the workpiece clamping device in a retracted position; and

15 Figure 9 is a section through the work clamp in a clamping position;

The workpiece clamping device shown in Figures 1 to 4 comprises a headstock 1, a chuck 2 rotatable about a generally horizontal axis A, and a V-block clamp 3 for clamping a cylindrical workpiece 4 in the rotatable chuck 2. As shown in Figures 2 and 3, the workpiece 4 is clamped by the V-block clamp 3 with its central longitudinal axis C extending parallel to the axis of rotation of the chuck 2. The axis C of the workpiece is offset from the axis of rotation A by a distance so that as the chuck 2 rotates, the clamped workpiece revolves in an orbital path P around the axis A. Different positions of the workpiece 4 in its orbital path are shown in broken lines in Figure 3. Figure 4 shows a
20 workpiece 4' of larger diameter clamped by the V-block clamp 3.

The workpiece clamping device of Figures 1 to 4 forms part of a CNC multi-axis grinding machine which has a cutting tool 5 movable relative to a workpiece 4 clamped in the chuck 2 by the V-block clamp 3. For this purpose, the CNC machine has an A-axis actuator 11 for moving the cutting tool 5 in the
30 direction of the axis of rotation A of the chuck 2, a Y-axis actuator 12 for

moving the cutting tool 5 in the direction of a horizontal Y-axis perpendicular to the A axis, and a Z-axis actuator 13 for moving the cutting tool in the direction of a vertical Z axis perpendicular to the A and Y axes. In a conventional CNC machine, the A axis is usually termed the X-axis.

5 Movement of the cutting tool 5 by the actuators 11, 12, 13 is controlled by a computer numerical control system including a programmable control unit (PCU) 6, a trajectory interpolator 7, a co-ordinate transform module 8 and a position controller 9 as shown in Figure 5. PCU 6 is programmed with a programmed path for the cutting tool 5. The trajectory interpolator 7 receives
10 motion commands from the PCU 6 and calculates axis vector values which are passed to the co-ordinate transform module 8. The co-ordinate transform module 8 transforms the axis vector values into joint vector values and the position controller 9 produces position control signals from the joint vector values which are passed to the actuators 11, 12 and 13.

15 The control system differs from a conventional CNC machine control system in that it is programmed to compensate automatically for the offset of the workpiece axis C from the A axis of the rotatable chuck 2. This is achieved by programming the co-ordinate transform module 8 to recalculate the position command during each machine update period. The recalculated position
20 commands control the movement of the cutting tool 5 by means of the position controller 9. This does not require complicated re-programming of a conventional CNC machine control system, because the required adjustments in the Y and Z axes can be simply calculated from the known offset d. For
example, the Y-axis adjustment is $d \sin \theta$ and the Z-axis adjustment is $d \cos \theta$,
25 where θ is the angle between a vertical line passing through the A axis and the line joining the workpiece axis C and the axis of rotation A of the rotatable chuck 2 at any particular position of the workpiece 4 as it moves in its orbital path P around the axis A. Further, as the V-block clamp 3 is fixed at a constant distance away from the axis of rotation A of the chuck 2, it is a relatively
30 simple matter to calculate the offset d from the diameter or radius of the

cylindrical workpiece 4. For this purpose, the trajectory interpolator 7 may include input means for inputting cylinder radius or diameter values. Alternatively, the radius of a workpiece could be obtained by digitising.

The V-lock clamp 3 of a CNC machine in accordance with the invention can hold workpieces of a range of diameters as illustrated by Figures 3 and 4. It is only necessary to enter the radius of the particular workpiece clamped by the V-block clamp 3 as an input to the trajectory interpolator 7, and then the coordinate transform module 8 can automatically calculate the offset d and the required adjustments for the cutting tool 5 in the directions of the Y and Z-axes.

10 A preferred form of V-block clamping assembly 20 is illustrated in Figures 6 to 9. The clamping assembly 20 comprises a workpiece holder housing or chuck 30 secured to a rotatable headstock 40 and a pneumatically operable clamping mechanism 50.

The chuck 30 is formed from a front part 31 and a rear part 32, each of which is of hollow form having a respective cavity 33, 34 to receive the clamping mechanism 50. The front part 31 has a cylindrical rear portion 35 and a frustoconical front portion 36 having a conical surface 37 extending forwardly from the cylindrical rear portion 35 to a flat front end surface 38. A workpiece-receiving opening 39 is provided in the front end surface 38 and extends rearwardly to the cavity 33. The lower part of the opening 39 has inclined planar surfaces 41 which form a fixed, V-shaped jaw 42 of the V-block clamping assembly. The V-shaped jaw 42 is fixed relative to the central axis of rotation A of the headstock 40 and chuck 30. The upper part of the opening 39 has a part circular surface 43.

25 The rear part 32 of the chuck 30 has a front portion in the form of an annular flange 44, a tapered intermediate portion 45 extending rearwardly from the front portion 44 and a cylindrical rear portion 46 at the rear end of the tapered intermediate portion 45. The annular flange 44 is secured to the front end of the headstock 40 by fixing screws 47 and the cylindrical rear portion 35 of the front part 31 is secured to the annular flange 44 by fixing screws 48.

30

Longitudinally extending bores 49 extend rearwardly from the conical surface 37 of the front part 31 of the chuck 30 to allow access to the fixing screws 47, 48 so that they can be tightened or loosened for assembly or disassembly from the front of the chuck 30 by means of a suitable tool, such as an allen key.

The clamping mechanism 50 comprises a movable clamping jaw 51 which is movable up and down towards and away from the V-shaped jaw 42 of the chuck 30 by a lever arm 52 and a pneumatically operated plunger 60. The movable jaw 51 is in the form of a self-centering pressure pad having a V-shaped lower surface 54 which is engageable with the upper part of a cylindrical workpiece 4 in the extended position shown in Figure 9 to clamp the workpiece 4 between the movable jaw 51 and the V-shaped jaw 42 of the chuck 30.

The clamping jaw 51 is generally triangular in side view and is pivotally mounted on the front end 55 of the lever arm 52. The rear end 56 of the lever arm 52 has a curved surface 57 and the lever arm 52 is arranged to pivot within the cavity 33 in the front part 31 of the chuck 30 about an intermediate pivotal mounting 58.

The pneumatically operated plunger 60 comprises a frustoconical plunger head 61 provided on the front end of a piston rod 62 which extends forwardly from pneumatic cylinder (not shown) into the cavity 34 in the rear part 32 of the chuck 30. The plunger head 61 has a conical surface 63 which engages the curved surface 57 of the rear end 56 of the lever arm 52. The piston rod 62 is guided for longitudinal movement relative to the rear part 32 of the chuck 30 by bearings 64. When the piston rod 62 and plunger head 61 are advanced under pneumatic pressure the rear end 56 of the lever arm 52 is raised, as shown in Figure 9. This lowers the front end of the lever arm 52 to move the clamping jaw 51 down towards the V-shaped jaw 42 of the chuck 30 to clamp a workpiece 4 for a machining operation. The pivotal mounting of the movable clamping jaw 51 enables the jaw 51 to engage a workpiece 4 over the entire length of the jaw 51. This provides more rigid clamping and assists in

increased accuracy of grinding during a machining operation.

The rear end 56 of the lever arm 52 is connected by a spring 59 to a fixed anchor point in the chuck 30. The spring 59 urges the rear end 56 of the lever arm 52 into its lower position when the piston rod 62 and plunger head 61 are retracted. This raises the front end of the lever arm 52 to allow a previously clamped workpiece 4 to be removed from the chuck 30 after completion of a machining operation.

As described above with reference to Figures 1 to 4, the V-block clamping assembly 20 is arranged to clamp workpieces of different diameters with the central longitudinal axis C of a clamped workpiece 4 being offset from the axis of rotation A of the rotatable chuck 30 and headstock 40 by a distance d. There is, however, one particular diameter of workpiece for which the central axis C of the workpiece 4 will coincide with the axis A. This does not, however, affect the programming or operation of the CNC machine because d = 0 for this special case.

The V-block clamping assembly described above is particularly advantageous in that it provides rigid support for a workpiece. This is in addition to other advantages of the present invention which include: less runout than conventional workpiece mounting assemblies; better repeatability; increased concentricity of the ground workpiece; and the flexibility of handling workpieces of varying diameters with a reduction in setup time as compared with conventional CNC grinding machines.

It will be appreciated that various modifications may be made to the preferred embodiment described above without departing from the scope and spirit of the invention. For example, it is conceivable that a different type of workpiece clamping arrangement from the V-block clamping assembly could be used in the broad method of the present invention.

CLAIMS

1. A method of controlling a CNC machine having workpiece mounting means for holding a workpiece and a cutting tool operable upon the workpiece under the control of the CNC machine, the workpiece mounting means being
5 rotatable about a first axis, the method being characterised by the steps of:
clamping the workpiece such that a longitudinal axis of the workpiece is parallel to the first axis and offset from the first axis by a known or calculated distance; and
programming the CNC machine to compensate for said offset during
10 operation of the cutting tool on the workpiece.
2. A method according to claim 1 wherein a workpiece having at least a cylindrical mounting portion is clamped with the central longitudinal axis of the cylindrical mounting portion extending parallel to, but offset from, the first axis so that the workpiece revolves in an orbit around the first axis, and the CNC
15 machine is programmed to compensate automatically for the offset when controlling movement of the cutting tool.
3. A method according to claim 1 or claim 2 wherein the workpiece is clamped by a first clamping jaw fixed relative to the first axis and a second clamping jaw movable towards and away from the second jaw.
- 20 4. A method according to claim 4 wherein the fixed clamping jaw is in the form of a V-block, having planar workpiece supporting surfaces extending at an angle relative to one another.
5. A method according to any one of the preceding claims wherein the CNC machine is programmed to recalculate position commands for the cutting
25 tool to compensate for said offset.

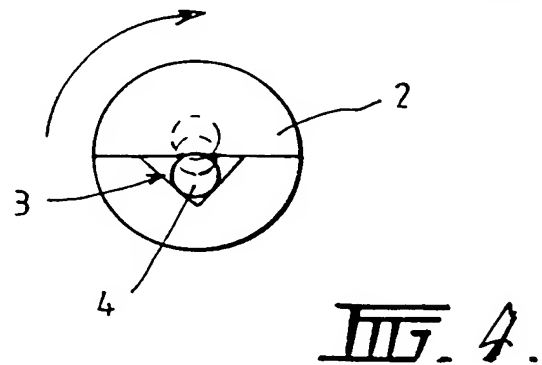
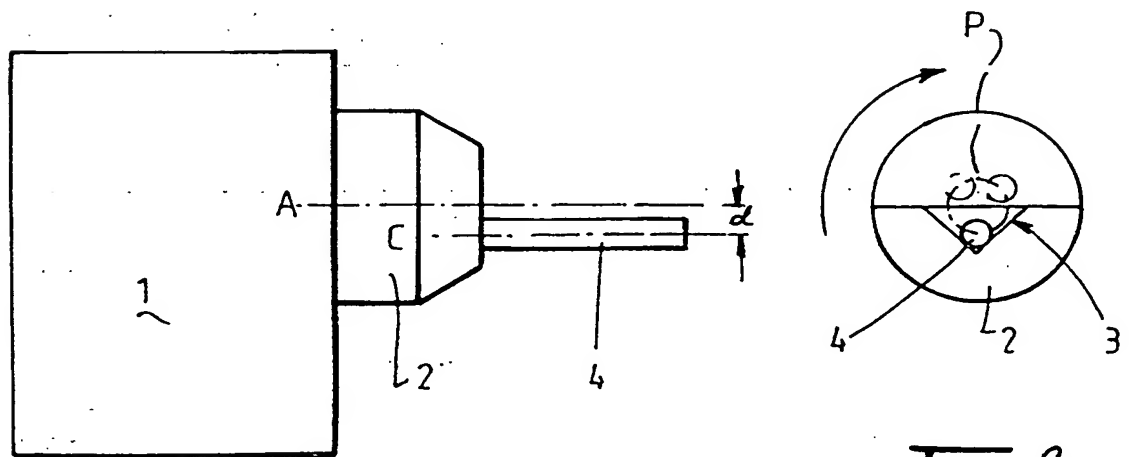
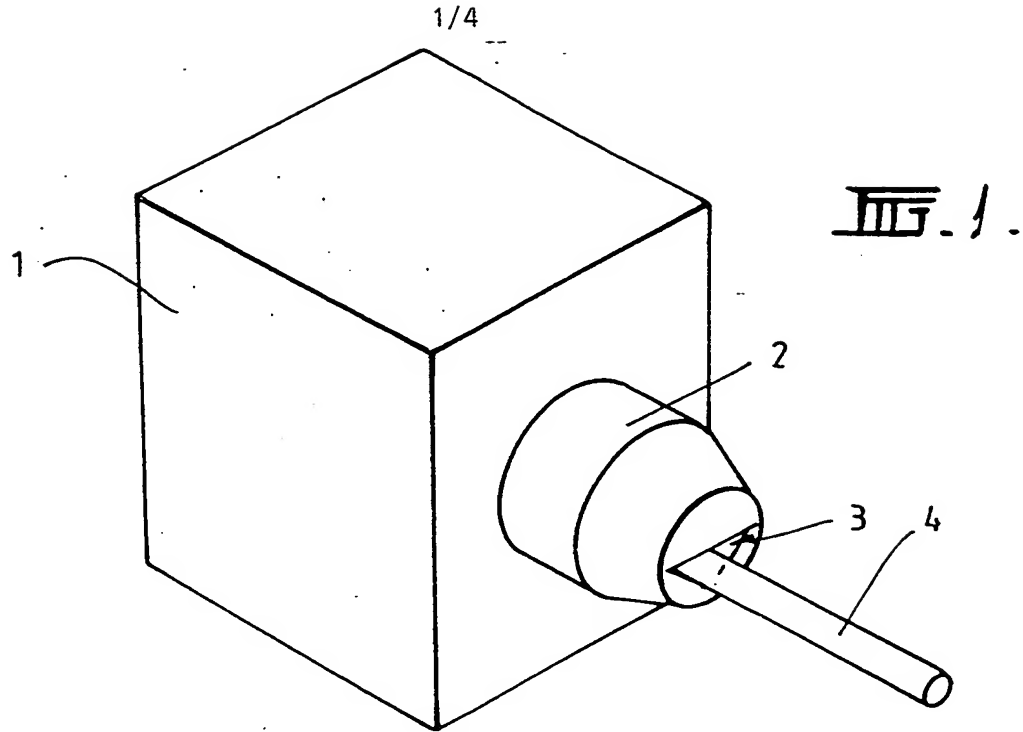
6. A method according to any one of the preceding claims wherein required adjustments for the cutting tool in the Y and Z axes to compensate for said offset are calculated from the offset d , the Y-axis adjustment being $d \sin \theta$ and the Z-axis adjustment being $d \cos \theta$, where θ is the angle between a vertical line passing through the first axis A and the line joining the longitudinal axis C of the workpiece and the first axis A at any particular position of the workpiece.
7. A method according to claim 2 wherein the offset is calculated from the diameter or radius of the cylindrical mounting portion of the workpiece.
8. A method according to claim 7 wherein the diameter or radius of the workpiece is obtained by digitising the workpiece.
9. A computer numerically controlled (CNC) machine having workpiece mounting means for holding and rotating a workpiece, and a cutting tool operable upon the workpiece under the control of the CNC machine wherein the workpiece mounting means is rotatable about a first axis and includes workpiece clamping means for clamping workpieces of different transverse dimensions in such a manner that a workpiece is clamped with a longitudinal axis of the clamped workpiece parallel to the first axis, the offset between the first axis and the longitudinal axis of the workpiece being known or calculated and wherein the CNC machine is programmed to compensate for said offset during operation of the cutting tool upon the workpiece.
10. A CNC machine according to claim 9 wherein the workpiece clamping means comprises a first clamping jaw that is fixed relative to the first axis about which the mounting means is rotatable and a second clamping jaw that is movable towards and away from the first clamping jaw.

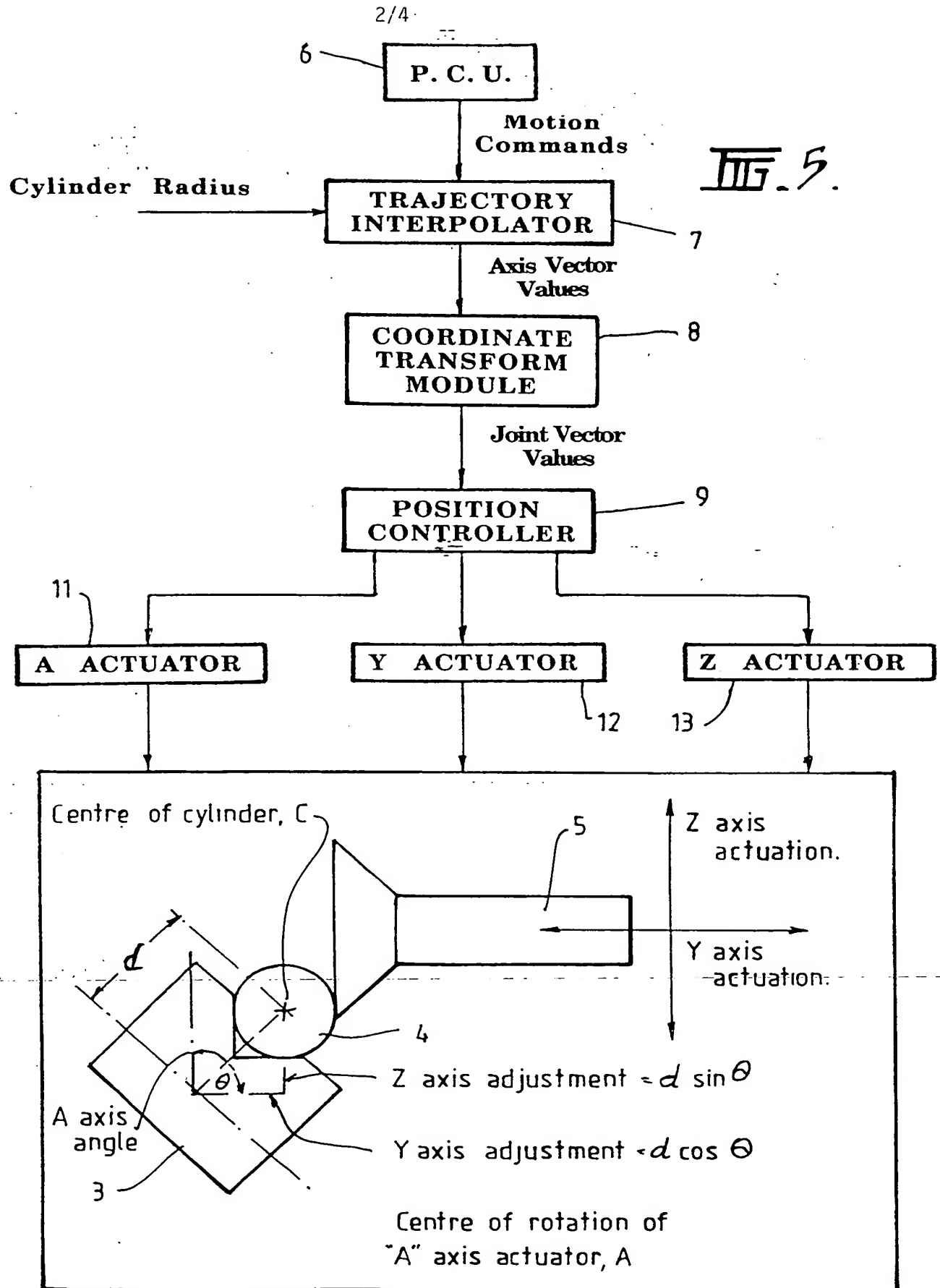
11. A CNC machine according to claim 10 wherein the fixed clamping jaw of the clamping means is in the form of a V-block, having planar workpiece supporting surfaces extending at an angle relative to one another.
12. A CNC machine according to claim 10 or claim 11 wherein the movable
5 clamping jaw is mounted on a pivotal lever arm.
13. A CNC machine according to claim 12 wherein the pivotal lever arm is pivotable by an operating mechanism including a plunger engageable with a rear end of the lever arm.
14. A CNC machine according to claim 13 wherein the operating
10 mechanism is pneumatically operable.
15. A CNC machine according to any one of claims 9 to 14 wherein movement of the cutting tool is controlled by a control system including a programmable control unit, a trajectory interpolator, a co-ordinate transform module and a piston controller.
- 15 16. A CNC machine according to claim 15 wherein the co-ordinate transform module is programmed to re-calculate position commands for the cutting tool to compensate for said offset.
-
17. A CNC machine according to claim 16 wherein the co-ordinate transform
20 module is programmed to utilize said offset to calculate required adjustments in the Y- and Z-axes for the cutting tool.
18. A CNC machine according to claim 17 wherein the offset is calculated from the diameter or radius of a cylindrical clamped portion of the workpiece.

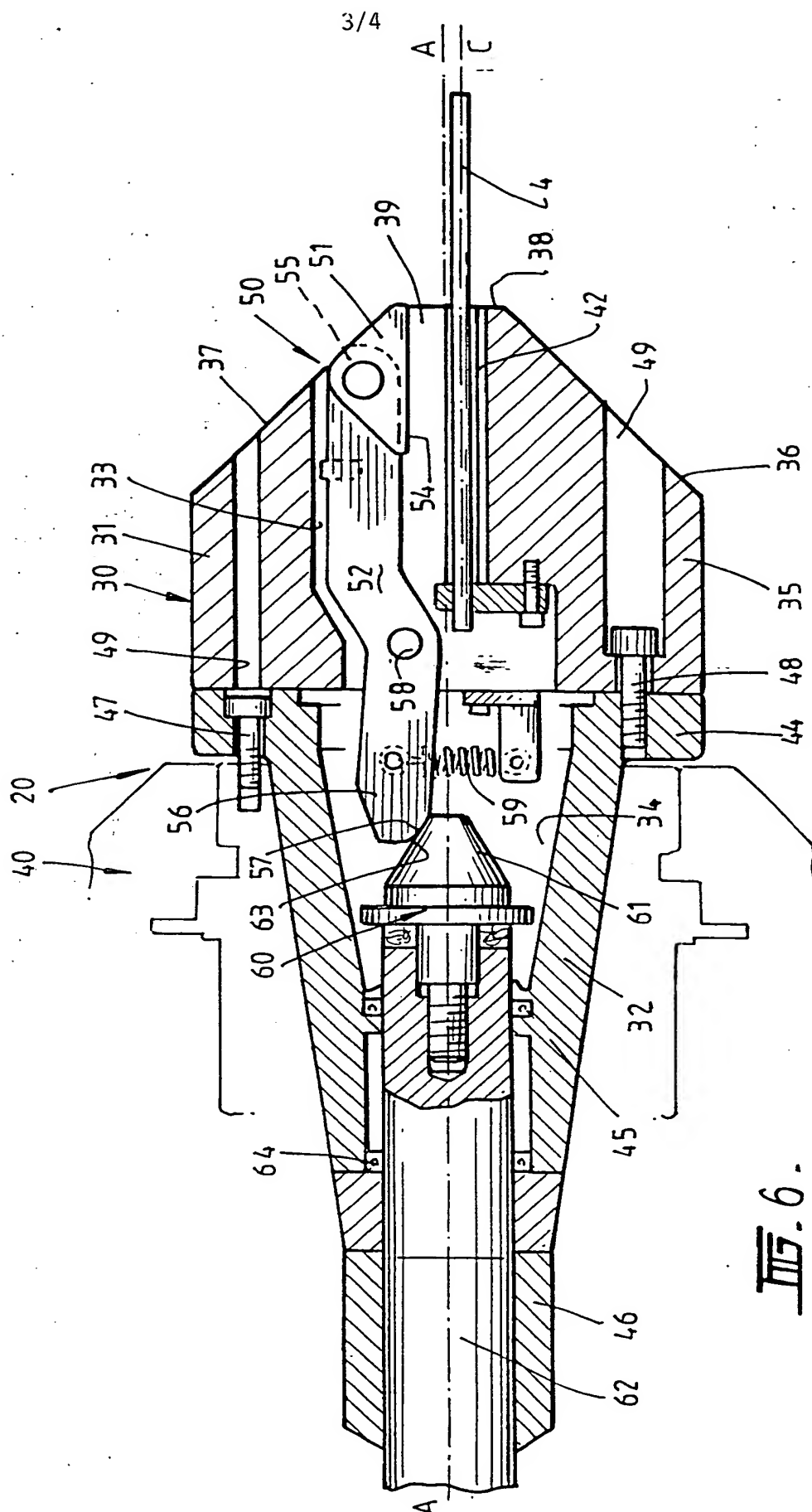
19. A CNC machine according to claim 18 wherein the control system includes input means for inputting cylinder diameter or radius values.
20. A CNC machine according to claim 18 or 19 including digitising means for determining the diameter or radius of a workpiece.
- 5 21. A computer numerically controlled (CNC) machine having workpiece mounting means for holding and rotating a workpiece, and a cutting tool operable upon the workpiece under the control of a part program, the workpiece mounting means being rotatable about a first axis and including workpiece clamping means having a first clamping jaw and a second clamping jaw, the
10 second clamping jaw being movable towards and away from the first clamping jaw, and wherein the first clamping jaw comprises a V-block, having planar workpiece supporting surfaces extending substantially parallel to the first axis and at an angle relative to each other.
- 15 22. A CNC machine according to claim 21 wherein the first clamping jaw is fixed relative to the first axis.
23. A CNC machine according to claim 21 or claim 22 wherein the second clamping jaw is mounted on a pivotal lever arm.
24. A CNC machine according to claim 23 wherein the second clamping jaw is mounted on a front end of lever arm, and the lever arm is pivotable by an
20 operating mechanism including a plunger engageable with a rear end of the lever arm.
25. A CNC machine according to claim 24 wherein the second clamping jaw is pivotally mounted on the front end of the lever arm.

26. A CNC machine according to claim 24 or claim 25 wherein the plunger of the operating mechanism is pneumatically advanced to move the second clamping jaw towards the first clamping jaw.

27. A CNC machine according to claim 24 or claim 25 wherein the second
5 clamping jaw is urged away from the first clamping jaw when the plunger is retracted.







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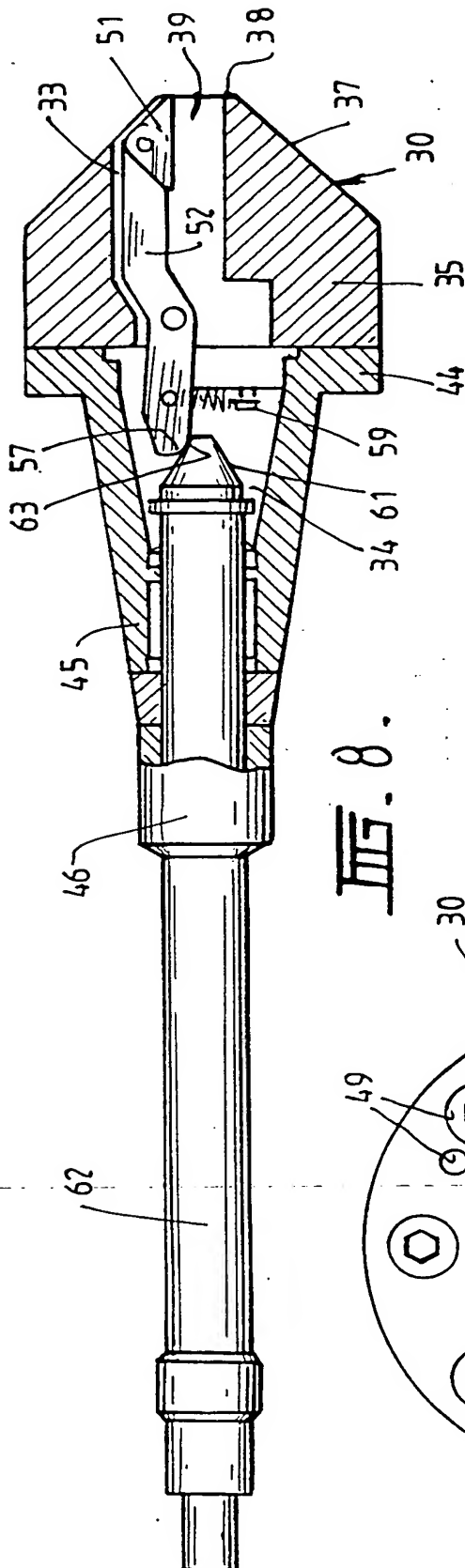


Fig. 8.

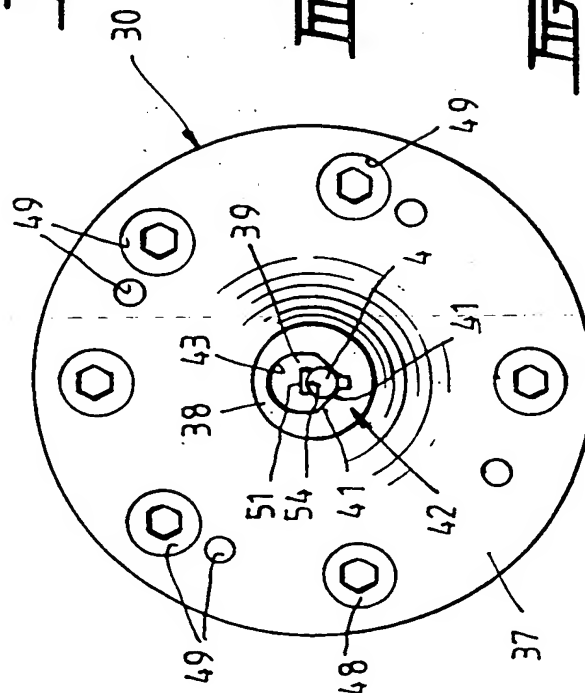


Fig. 7.

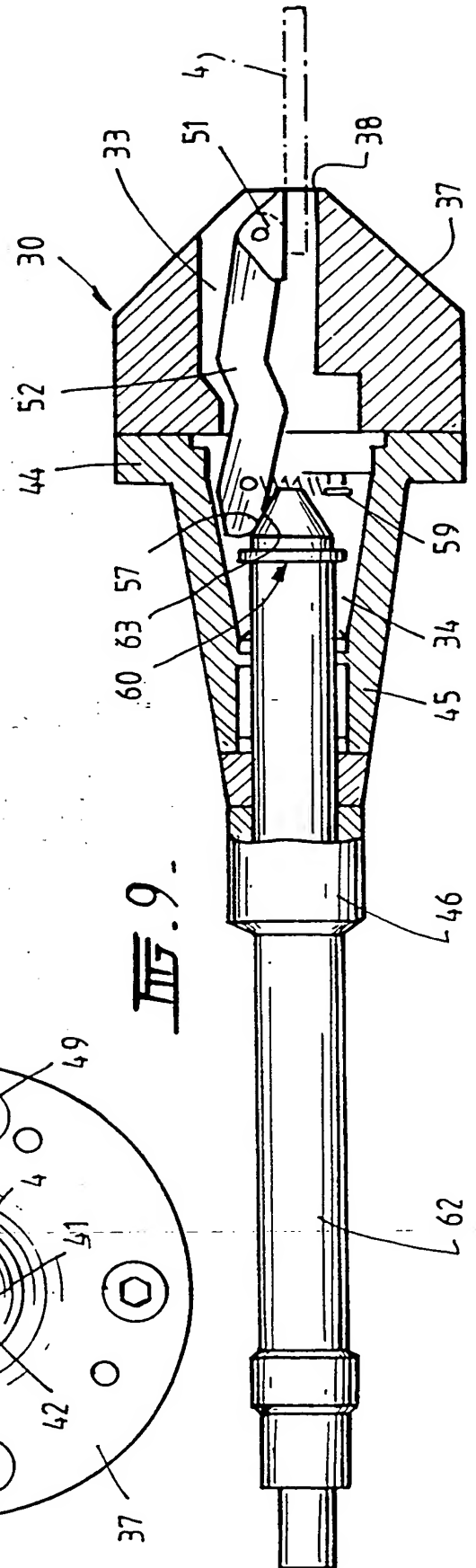


Fig. 9.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 98/00644

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl⁶: G05B 19/19, 19/404 B23Q 15/013 B23B 5/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G05B 19/19, 19/404 B23Q 15/013 B23B 5/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT : B23B, B23Q, offset

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5396821 A (OKUMURA et al) 14 March 1995 whole document	1-27
A	EP 0545655 A (GENERAL ELECTRIC COMPANY) 9 June 1993 whole document	1-27
A	Patent Abstracts of Japan, JP 07198336 A (RICOH CO LTD) 1 August 1995 whole document	1-27

☒ Further documents are listed in the
continuation of Box C

☒ See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
6 October 1998

Date of mailing of the international search report
16 OCT 1998

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 98/00644

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, JP 09101812 A (FANUC LTD) 15 April 1997 whole document	1-27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 98/00644

Information on patent family members

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
US	5396821	JP	5305501				
EP	545655	CA	2082708	EP	545655	JP	5257514
		US	5309646				